

PRIMARY REFERENCE CLOCKS USING INDOOR ANTENNAS

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Abstract

This paper discusses a new technology of synchronizing clocks and disciplining oscillators using CDMA cellular transmissions. Like cellular telephones, these receivers will operate in most buildings without rooftop antennas. They are reported accurate to within microseconds of UTC with stable frequencies available.

INTRODUCTION

UTC Time and Frequency Dissemination via the IS-95 CDMA Mobile Telecommunications Infrastructure

Base Station Transmissions in IS-95 CDMA Systems

- All use the same pilot pseudonoise (PN) spreading code
- All use the same carrier frequency (within an individual provider's system)

Base Station Transmissions in IS-95 CDMA Systems Must be Synchronized

- To control interface between cells:
 - ⇒ Cell-to-cell interference is controlled by having each base station transmit the pilot PN code with its own unique time offset relative to GPS time
 - ⇒ The pilot PN offsets must be maintained accurately or adjacent cells would interfere with each other

Base Station Transmissions in IS-95 CDMA Systems Must be Synchronized

- To allow a "soft hand-off" as the mobile user travels between cells.
 - ⇒ The mobile unit must be able to calculate the approximate time offset of the new base station's pilot PN code in order to rapidly acquire and lock to it before losing the current base station
 - ⇒ If the base stations are synchronized, and the mobile user decodes the neighboring cell PN offset data that it receives from the currently tracked base station, this can be achieved

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The IS-95 CDMA System Time Base is the GPS Time Scale Because...

- GPS is globally available
- GPS can maintain the required level of synchronization between base stations
 - ⇒ Less than 1 us while tracking a satellite
 - ⇒ Less than 10 us for up to 24 hours while in holdover (IS-95 spec) using either
 - A rubidium vapor local oscillator
 - An ultra-stable, ovenized quartz local oscillator with software temperature compensation

The IS-95 CDMA Signal Structure Supports Precision Recovery of GPS Time & Frequency

- Spread spectrum modulation at GPS-like chipping rate of 1.2288 Megachips/second
- Pilot PN code can be acquired using long integration time—no data modulation
 - ⇒ 32768 chip code repeats every 26.666...ms
 - ⇒ Base station pilot PN codes are offset from each other in 64 chip increments (52.08333....us)

The IS-95 CDMA Signal Structure Supports Precision Recovery of GPS Time & Frequency

- Cellular (881 MHz)/PCS (1960 MHz) carriers support GPS-like low-noise frequency recovery and aiding/smoothing of the code tracking loop
- Sync channel message: base station PN offset, UTC leap seconds and local time offset
 - ⇒ 1200 bits/second data is convolutionally encoded ($k=2$, $m=9$) to 2400 symbols/second
 - ⇒ Block interleaved with 2:1 redundancy to 4800 symbols/second
 - ⇒ CRC-30 performed on complete message
 - ⇒ Message repeated every 240 milliseconds

Received IS-95 Signal Level is Much Higher than GPS

- IS-95 coverage spec minimum is -100 dbm – at least 30 dB greater than GPS
- Cellular band carrier penetrates buildings to much greater degree than GPS
- Provides an excellent alternative in situations that are difficult for “direct” GPS

SUMMARY

CDMA “Indirect” GPS Performance Relative to “Direct” GPS

- Uncertainty in the propagation delay from base station to user limits absolute accuracy of the recovered UTC time to tens of microseconds.
- With stationary users, the time offset due to propagation delay is fixed and the repeatability and stability of the recovered UTC time is at the 100 ns level.
- With stationary users, the quality of the base station GPS receiver/oscillator system provides excellent transmitted frequency accuracy and stability which is virtually reproduced with a well-designed receiver.

Questions and Answers

JEREMY ELSON (UCLA): I am wondering if anybody has talked about trying to recover position by locking to, let's say, four CMA space stations the same as you would lock on to four GPS satellites.

DONALD MITCHELL: That's a good thought. You could certainly do that. Because if you're looking at the offsets that are received, then most certainly you could be able to determine your location by looking at the offsets that you receive from three carriers. You have four carriers, and it makes it even better. So yes, that's a possibility. Although, like I say, I am not aware of anybody doing that. That could be something that is going on.

I really wasn't aware of this until I heard about it, but I think the first real notice I had that somebody was actually doing something in this area was Ed Butterline at the ION in '99 bringing the subject up.